TUMORS OF THE MUSCULOSKELETAL SYSTEM: MAGNETIC RESONANCE IMAGING AND COMPUTEED TOMOGRAPHY

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M AGNETIC resonance imaging is becoming an important diagnostic tool for diseases of the musculoskeletal system. Its advantages include extraordinary contrast resolution for soft tissues with properly selected pulse sequences, freedom from artifacts due to dense bone, and ability to produce images in any plane. At the present time the most promising applications are in some of the "dark areas" of conventional imaging, including computed tomography. Mass lesions of the extremities have been particularly difficult to image, especially in children and in patients with a limited amount of fat separating the tissue planes. The bone marrow has been difficult to evaluate because the axial presentation of computed tomographic images is poorly suited to display of large regions of the marrow and because conventional radiographs and radionuclide scans are relatively insensitive to changes within the marrow. For demonstration of the spinal cord and spinal nerve roots within the spinal canal, other imaging modalities require the use of intrathecal contrast. Even so, the thoracic spinal cord is notoriously difficult to image. Finally, the periarticular tissues—cartilage, fibrocartilage and tendons—have been difficult to display without contrast and in an anatomically relevant fashion. In each of these areas magnetic resonance imaging is making an important contribution.

Most pathologic conditions of the musculoskeletal system exhibit longer T1 and T2 values than muscle. For this reason, in "T1 weighted" images they yield relatively little signal, tending to be dark on the images. On T2 weighted images, the reverse is true. Fat appears bright in both types of sequences because of relatively short T1 and long T2. Muscle is relatively dark on both sequences.[1] Therefore, when maximum contrast between a lesion and contiguous fat is desirable, a T1 weighted sequence is preferred. When contrast with muscle is desirable, T2 weighted images result in a bright signal

from the area of tumor contrasting with the relatively darker signal from adjacent muscle (Figure 1). Since it is often desirable to know the longitudinal extent of a lesion within bone marrow and the compartmental distribution of the lesion within muscle, we have found that a satisfactory examination includes a T1 weighted coronal or sagittal projection and a T2 weighted axial image (Figure 2).

Magnetic resonance imaging contributes four basically different types of information to the study of musculoskeletal neoplasms. Because of exquisite soft tissue contrast, it is helpful in identification of the existence of a pathological lesion. It helps to elucidate the extent of the lesion, including its proximal to distal spread, the compartmental anatomy affected by the lesion and the proximity to such major structures as arteries and nerves. It can sometimes assist in the diagnosis of the lesion and it can be helpful in evaluating the response to therapy and the presence of recurrence.

IDENTIFICATION OF LESIONS

Just as computed tomography represented a significant advance in the ability to identify soft tissue lesions, especially in the thicker parts of the body, so magnetic resonance imaging represents another leap forward in this regard. Lesions entirely invisible by other imaging techniques can be demonstrated by magnetic resonance imaging.[2] (Figure 3). A limited number of studies have been done as to how to improve the intensity differences between musculoskeletal tumors and adjacent normal tissue.[3] These studies have led to the general conclusion that strongly T2 weighted images (TR > 1,500) are best suited for identification of lesions adjacent to or within muscle.

Coronal or sagittal T1 weighted images demonstrate the proximal to distal extent of the lesion within bone marrow in a particularly convenient fashion. Skip metastases and other intramedullary metastases can also be detected in this way. Computed tomography can also be used for this purpose, especially with careful attention to the Hounsfield numbers within the bone marrow.[4] Some authorities have urged that computed tomographic scanning should include the entire length of the affected bone to identify the presence of skip metastases.[5] However, the cross-sectional display of the scan makes multiple side-to-side comparisons necessary and does not afford the easy comprehension of longitudinal extent given by magnetic resonance.

The extreme sensitivity of magnetic resonance to contrast differences can sometimes be a double-edged sword. The abnormalities detected by magnetic resonance are not necessarily limited to the volume occupied by the
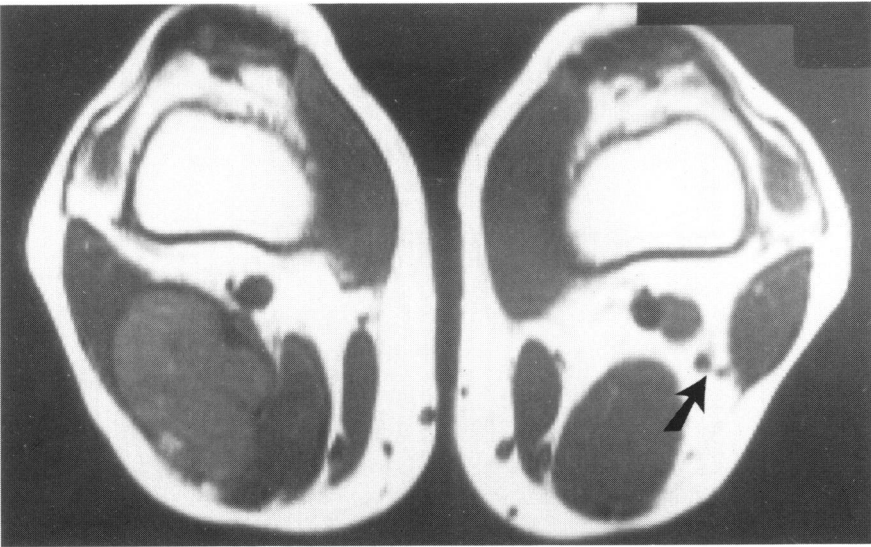
Fig. 1a. On T1 weighted images (SE TR=500,TE=30) this neurofibrosarcoma arising from the common peroneal or tibial branch of the distal sciatic nerve gives a weak signal. The lesion thus appears dark, contrasting strongly with the subcutaneous fat and bone marrow, but weakly with muscle. The normal nerves on the opposite side are indicated by an arrow.
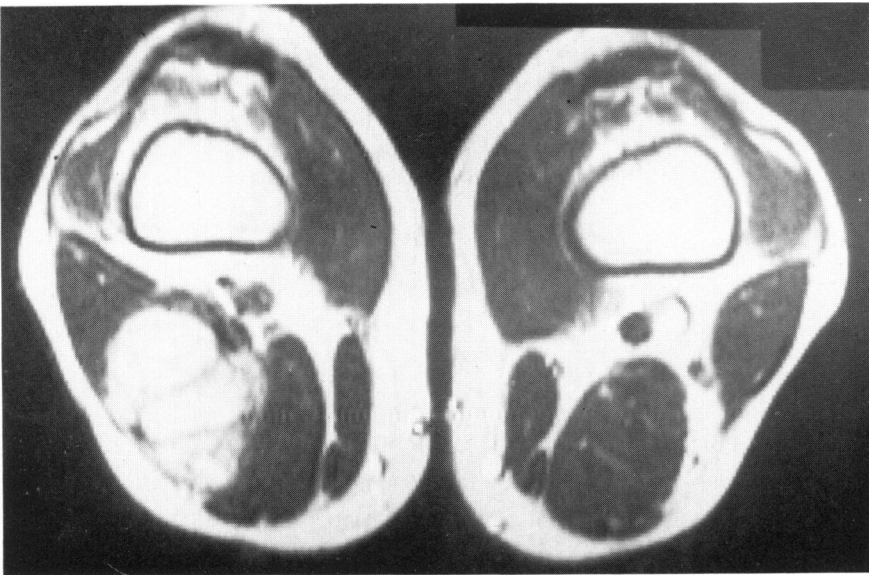

Fig. 1b. On T2 weighted images (SE TR=2000, TE=60) the sarcoma appears bright, similar to fat in intensity, and contrasting strongly with muscle.

Fig. 2a. T1 weighted coronal images (SE TR=500, TE=32) demonstrate the proximal and distal intraosseous margins of this Ewings sarcoma (arrows).
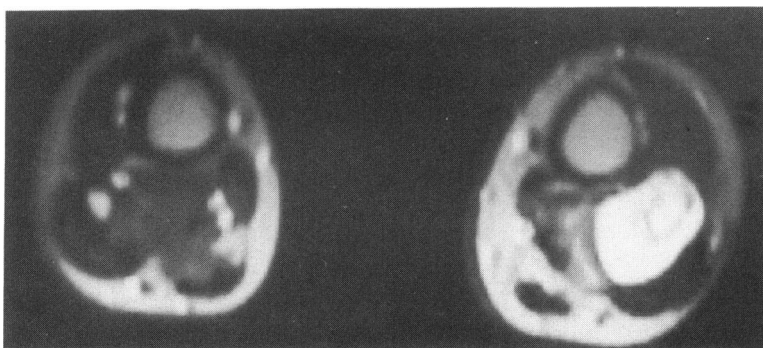

Fig. 2b. T2 weighted axial image (SE TR=2000, TE=120) reveals the large extraosseous soft tissue mass.

neoplasm. Large abnormal areas can sometimes be seen surrounding the lesion, presumably due to inflammation, hemorrhage, edema, or muscular atrophy. In some cases, extended epiphenomena of this type can suggest the possibility of tumor when no neoplasm is present. We have noted extensive changes in the bone marrow contiguous to stress fractures, within muscle adjacent to loci of calcific tendonitis and myositis ossificans, and contiguous to tumors due to muscular atrophy (Figure 4).
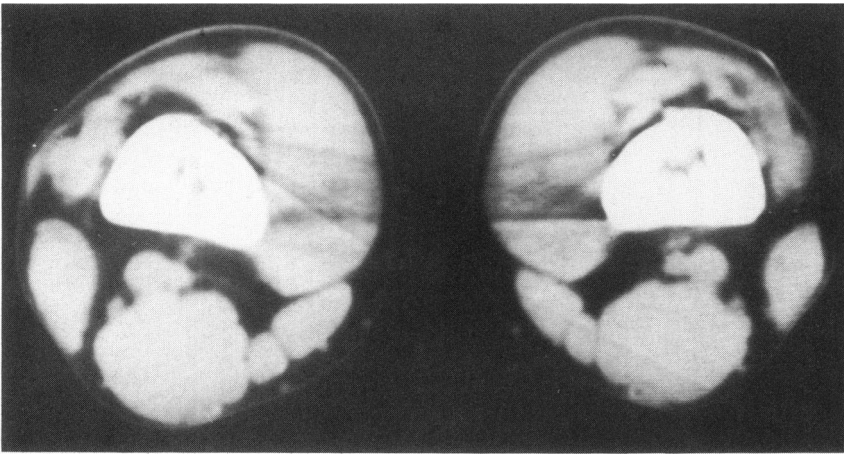
Fig. 3a. This 21-year-old student had a mass which was palpable in the left distal thigh when he was upright. CT scan with and without contrast material was normal.
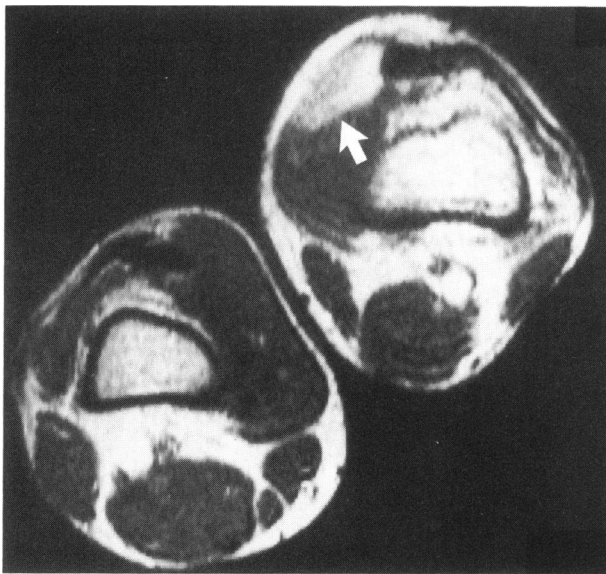

Fig. 3b. MRI with T2 weighting (SE TR=2000, TE=60) reveals a lesion of the vastus medialis (arrow) which proved to be a hemangioma.

Such phenomena, while potentially misleading, do not invalidate the clinical usefulness of magnetic resonance. Subtle changes in signal intensity are usually identifiable at the margins of the true tumor. Somewhat analogous findings can be seen with radionuclide scans in which an "extended uptake pattern" has been identified by Hudson in association with certain bony neoplasms.[6]
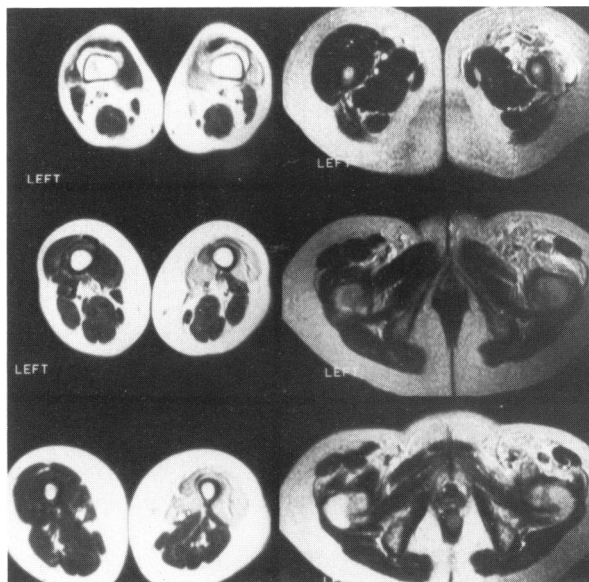
Fig. 4. Six different levels through the thigh demonstrate an abnormality of the vastus muscles, the rectus femoris, and the pectineus muscle. The tensor fascia lata is spared. This pattern of muscular abnormalities reflects the distribution of the femoral nerve. The patient was ultimately demonstrated to have a lymphoma of the pelvis which caused the neuropathy. Interestingly, the lymphoma was demonstrated by CT, but not by MRI>

Orthopedic surgeons who treat tumors of the extremities regard the distribution of the lesion within the fascial compartments of the extremity as of great importance. Lesions remaining within a single compartment are thought to have a better prognosis than lesions which violate compartmental boundaries. Furthermore, resection of an entire compartment containing a lesion is radical surgery, similar in efficacy to amputation of the extremity.[6]

Magnetic resonance imaging can often clarify the compartmental distribution of an extremity lesion when the computed tomogram is obscure. In general, fascial boundaries are better demonstrated with magnetic resonance than with tomography because the characteristically strong signal received from fat within the fascial planes contrasts with extremely weak signal received from dense fibrous tissue (Figure 5). Therefore, when the compartmental boundaries are formed by soft tissue, the magnetic resonance scan yields a better appreciation of the compartmental distribution of the lesion. However, when the boundaries are formed by very thin margins of cortical bone or periosteal new bone, the weak signal from these structures can
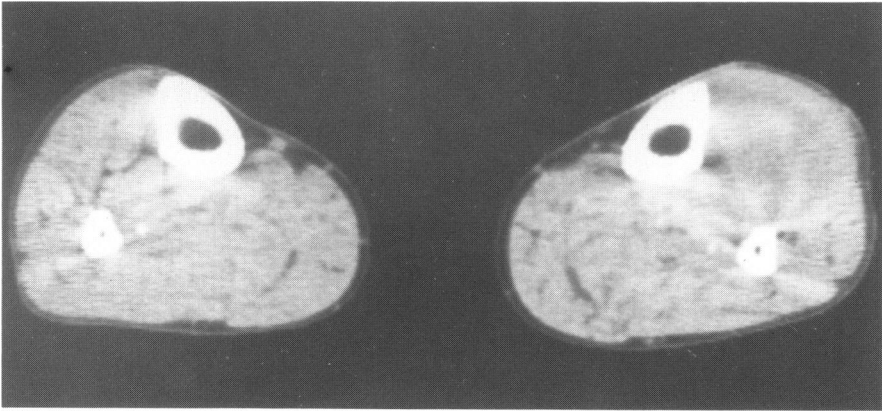
Fig. 5a. A fibrosarcoma of the anterior compartment of the leg is easily visible on CT scan with contrast. It cannot be determined whether the lesion has transgressed the interosseous septum to involve the posterior compartment.
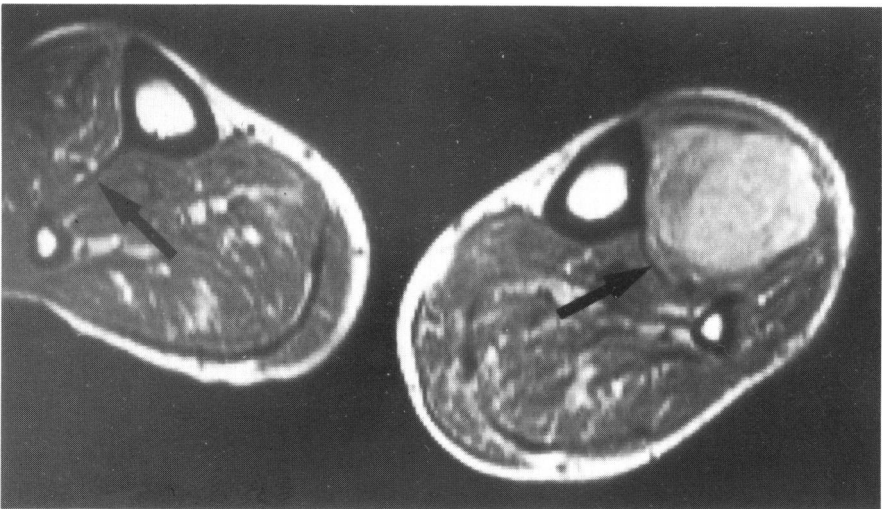

Fig. 5b. MRI done with T2 weighting (SE TR=1500, TE=30) clearly demonstrates the interosseous septum displaced posteriorly, but not transgressed (arrow), thus demonstrating that the pathology is limited to the anterior compartment.

be overwhelmed by stronger signal received from the adjacent neoplasm. Due to partial volume effects, it may become impossible to recognize a thin bone at this boundary. For this reason, when compartmental boundaries are formed by bone, computed tomography is preferable.

The relationship between the neoplasm and contiguous major arteries and nerves is not always demonstrated by either method, and angiography is

sometimes still required. The largest blood vessels, such as the superficial femoral and the popliteal arteries, are relatively well seen by magnetic resonance because the rapidly flowing blood in these structures produces a very weak magnetic resonance signal which contrasts strongly with its surroundings. Computed tomography is somewhat less satisfactory for this purpose even with intravenous contrast material. Major nerves are also usually seen somewhat better with magnetic resonance than with tomography because they frequently run in fascial planes where they are surrounded by fat (Figure 1).

Extension of lesions into the spinal canal is better demonstrated by magnetic resonance imaging than by computed tomography. Clinical usefulness is enhanced by images in the sagittal plane, the strong signal from epidural fat, and the ability to demonstrate the spinal cord and conus without intrathecal contrast. Nerves within the lateral recesses of the spine and within the sacral neural foramina are better seen by computed tomography.

In general, magnetic resonance has been less successful in providing specific diagnoses. Extensive study has been done to determine whether the relaxation parameters T1 and T2 may be used to predict whether a lesion is benign or malignant. It would appear that no such determination is possible. Specific tissue types can rarely be recognized from the T1 and T2 values. A few tissues have characteristic relaxation parameter "signatures." Fat can be recognized by its very short T1 (approximately 250 ms) and relatively long T2 (55 ms). However, liposarcomas have prolonged T1s similar to other types of soft tissue sarcomas, and may have variable prolongation of the T2.[8] Similarly, on computed tomography benign lipomas are extremely lucent and easily identified, but malignant tissues exhibit a spectrum of attenuation extending from lucent to density indistinguishable from other types of soft tissue.

Occasionally, the nature of a lesion can be identified on morphologic grounds, as, for example, when fluid-fluid levels are seen within an aneurysmal bone cyst.[9] In most instances, however, magnetic resonance imaging is a sensitive but nonspecific tool useful for recognition of lesions and determination of extent rather than diagnosis.

Magnetic resonance has proved useful for evaluation of patients after therapy. It is highly sensitive to recurrences of lesions within soft tissue, which can usually be distinguished from postoperative scar based on signal intensity (Figure 6). Like computed tomography, it can be used to follow the change in tumor size following chemotherapy or radiation therapy. Characteristically increased signal brightness within irradiated normal bone marrow has been described. [10] We have found no useful changes in the signal
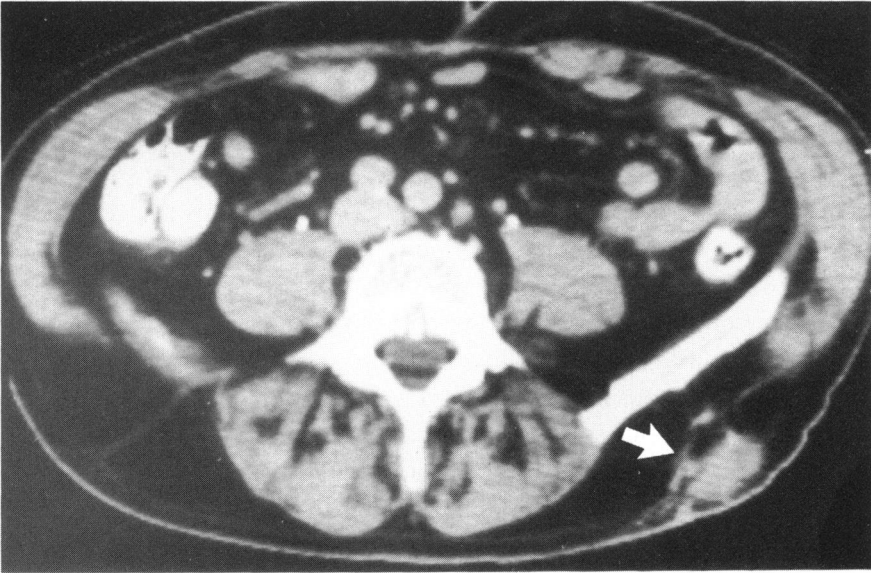
Fig. 6*a*. Following surgery for malignant fibrous histiocytoma CT demonstrates a density within the subcutaneous soft tissues which could be either scar or recurrent tumor (arrow).
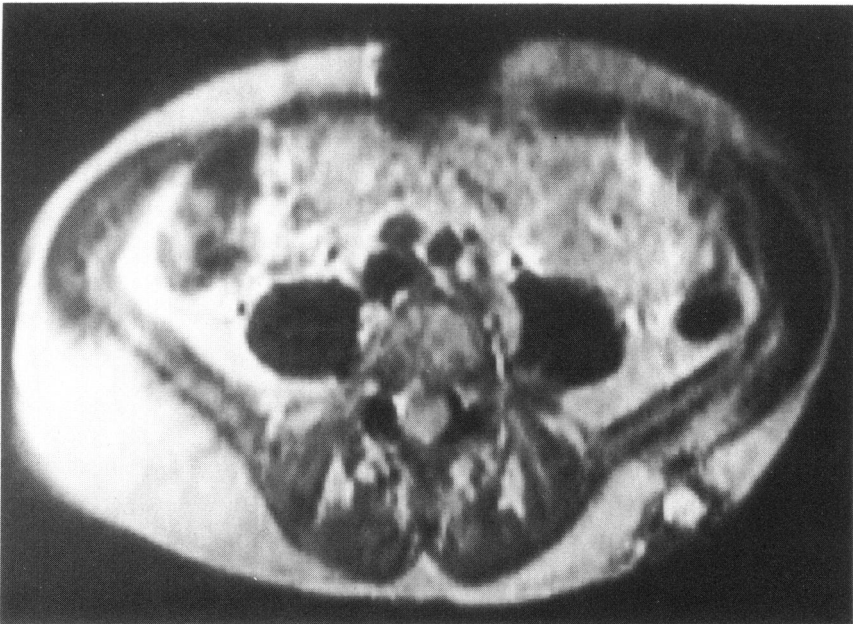

Fig. 6*b*. MRI (SE TR=2000, TE=60) demonstrates an area of bright signal due to tumor which is clearly distinguishable from the darker area of scar.

properties of treated neoplasms. Magnetic resonance imaging can sometimes be performed in the presence of metallic hardware, but at other times the presence of hardware within the imaging field severely degrades the image.

The full potential of magnetic resonance imaging for the musculoskeletal system and for musculoskeletal tumors in particular has not yet been explored. There is some evidence that the biochemical composition of individual types of neoplasms is a function of tumor grade.[11] In particular, the water content of high grade cartilage lesions has been shown to be greater than the water content of low grade lesions. Using magnetic resonance spectroscopy, we have been able to show that the water content of cartilage tumors can be predicted by the T1 value.[12] It is possible that the relaxation values may be useful as an indicator of lesion grade when comparison is made to other lesions of the same histologic type. Magnetic resonance spectroscopy can also be done in vivo with the use of high field magnets (1.5 to 2 tesla). Nidecker et al. have used in vivo p-31 MR spectra to demonstrate high adenosine triphosphate content in three actively growing bone tumors, indicating the active metabolism of the tumor.[13] This is an exciting advance that may also be helpful in predicting the prognosis of the sometimes unpredictable lesions.

Alterations in T1 and T2 relaxation times have been observed in dystrophic muscles[14] and in muscles of dehydrated patients.[15] It has not yet been possible to demonstrate alterations due to venous or arterial stasis or to postischemic hyperemia. Other research efforts still on the horizon include exploitation of the sensitivity of the magnetic resonance image to blood flow to evaluate the vascularity of tumors and evaluation of fat and water content of lesions with chemical shift imaging.[16]

It is impossible to be definitive about the future role of magnetic resonance imaging in evaluating diseases of the musculoskeletal system. A few things seem certain, however. The recent past has been remarkable, the present time is exciting, and the future appears bright.

SUMMARY

Magnetic resonance imaging is making an important contribution to the evaluation of musculoskeletal neoplasms. It is the most sensitive modality for detection of soft tissue abnormalities and is of great value in demonstration of the compartmental distribution of soft tissue lesions. It can reveal the relationship between the neoplasm and major blood vessels and nerves in some cases. It is extremely useful in distinguishing between postopera-

tive scar and tumor recurrence. Its drawbacks include inability to demonstrate thin bony margins and inability to distinguish between tumor and contiguous hemorrhage, atrophy, or edema.

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